

NASA TECHNICAL MEMORANDUM

1N-91  
46792  
NASA TM-88510  
P-28

PARQUET: REGIONS OF AREAL PLASTIC DISLOCATIONS (ON VENUS)

A.L. Sukhanov

Translation of "Parket: Oblasti Plozhchadnykh Plasticheskikh Dislokatsiy",  
Geotektonika, "Nauka" Press, Moscow, No. 4, July-August 1986, pp. 60-76

(NASA-TM-88510) PARQUET: REGIONS OF AREAL  
PLASTIC DISLOCATIONS (ON VENUS) (National  
Aeronautics and Space Administration) 28 p  
CSCL 84B

N87-15147

Unclas

G3/91 43666

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546  
October 1986

ORIGINAL PAGE IS  
OF POOR QUALITY

STANDARD TITLE PAGE

1. Report No. NASA TM-88510	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Parquet: Regions of Areal Plastic dislocations (on Venus)	5. Report Date October 1986	6. Performing Organization Code
7. Author(s) A.L. Sukhanov	8. Performing Organization Report No.	10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, California 94063	11. Contract or Grant No. NASW-4005	12. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington D.C. 20546	14. Sponsoring Agency Code	
13. Supplementary Notes Translation of Parket: oblasti plozhchadnykh plasticheskikh dislokatsiy IN: Geotektonika (Geotectonics), NO.4, July-August 1986, "Nauka" Press, Moscow, pp. 60-76 (ISSN 0016-853X) (UDC 551.24+523.4.42)		
16. Abstract The extensive flat elevations of the northern hemisphere of Venus are covered with frequently intersecting lines of dislocations, resembling the outline of a giant parquet. In the internal sections of these regions we find grabens and regions of extension, and on the periphery lobe-shaped flow structures. The parquet was formed after the beginning of the formation of the lava plains, but covered by the youngest lava. These structures apparently arose partly because of the dragging of blocks of crust by the asthenospheric flows, and partly in the gravitational sliding of such heated blocks in the partial melting of their base. It is possible that these elevations occupy on Venus the place of the Earth's rift systems.		
17. Key Words (Selected by Author(s))	18. Distribution Statement unclassified-unlimited	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 28
		22.

## PARQUET: REGIONS OF AREAL PLASTIC DISLOCATIONS (ON VENUS)

A.L. Sukhanov

### Introduction

Regions of areal dislocations, called parquet because of their peculiar patterned surface (1), occupy nearly  $9 \cdot 10^6 \text{ km}^2$  of the photographed territory. They are represented by several groups of isometric sections (of 0.5-2 million  $\text{km}^2$ ) and are separated by small monadnocks among the lava fields. /60\*

A structure of the parquet is formed as a rule of two or three systems of intersecting swells and grooves with characteristic widths 5-10 (up to 20 km) and lengths between several tens to a few hundred kilometers. As a whole these swells and valleys form orthogonal, diagonal and v-shaped outlines, deferring both in dimensions and in structure from the fold-fault framing of Lakshmi and from the belt of linear structures in the plains. In places the structures resemble the outlines of flow of the lavas, glaciers and rocky glaciers, but increase ten and hundred fold. All these outlines change both with the limits of each region, and in transition from one region to the other. The common element is only the constancy with which they cover enormous territories.

We give below the description of the main regions of development of the parquet, from the chaotic, disorderly sections to the sections where the structures reveal preferred orientation.

Region Between the Plains Atalanta and Niobe  
(47-57° latitude north, 125-143° longitude east)

The region is as a whole a rectangular block of approximately 500 x 1500 km, extended in the northwest direction, raised by 0.5-1.7 km over the surrounding plain. Its entire surface broken up by irregular ridges and clearly visible furrows; some of them are directed on the whole parallelly to the boundaries of the

---

\*Numbers in the margin indicate pagination in the foreign text.

block, others are located on the continuation of the belt of linear structures, coming from the south, but in general these fine (in places up to the limit of resolution) ridges and furrows do not have a definite orientation, they are bent irregularly in direction, intersect each other under different angles and usually have indistinct ends. On the elevated sections slightly deformed features of craterlike structures may be seen of diameters 50-150 km, and in the depressions this block is covered by young lava fields and fine volcanic cones. As compared with regions described later, no clear traces are visible here of considerable horizontal movements, and therefore this parquet is conventionally designated as "standing". /61

The section of diameter nearly 500 km at  $40^{\circ}$  latitude north and  $107^{\circ}$  longitude east having a slight particular relief has approximately the same appearance.

#### Region of Telluria

This region is in the form of a flat cupola of diameter nearly 1500 km and height 1.5-2 km over the surrounding locality. Its entire surface is corrugated with frequent intersecting ridges and furrows in several directions (fig. 1, photo 16 in (1)). The northwestern and northeastern directions predominate. The most uniform rectilinear structures (mostly faults) are detected over the entire cupola, dividing it into large blocks, and are hidden under the lavas of the surrounding plains. The space between them is filled with smooth lineaments extending approximately 20-100 km, having as a whole the same orientation; they are not combined into any belt, and cover uniformly the entire area. This orthogonal network is manifested most clearly at the flattened top of the cupola where the lineaments of other directions are regularly encountered. But with the approach to the edges of the cupola, where the slope increases, this outline changes into u-shaped and loop-shaped structures, directed as a whole subradially to the central region of the cupola and testifying to the plastic movement of the material downward along the slopes, although the slopes here do not exceed 1.5:1000. Along the western slope of the cupola a submeridional region of faults and narrow grabens passes, marking the rear portion of the rupture of the large plates, sliding towards the west on a gentle slope; here the plate is divided into several individual slivers, each of which is broken up into fine faults.

On the southern slope of the cupola we also see signs of movement of the material downward on the slope: here structures have developed, recalling the large flows of viscous lavas, over a distance of up to 300-400 km. On their surface we see characteristic buckling swells, jets and extended depressions, and the material of the flow in some places covers clearly the adjacent region.

In the eastern section of the charted territory we find a submeridional region of faults, forming a graben shaped valley, which separates the eastern portion of Telluria; it is more difficult to judge the latter because of gaps in the photograph.

In the southwestern section of the arch we find troughs with diameter up to 30-150 km, filled with lavas. As a rule, the troughs are framed by characteristic pits with elevated edges which may be formed in the separation of the hanging walls of the solidified lava lakes from their edges and their collapse. The melts either emerge to the surface from under the submerged wall filling the depressions, or were partly drained into the neighboring trough, located gypsometrically lower. The chain of such depressions extends from the axis of the arch to the southeast on the bottom of the wide valley. In the wide flat edges of this valley, the orthogonal network of rectilinear faults disappears, replaced by irregular outlines of flow, isometric hills and depressions, meandering furrows and swells. It is apparent that the plasticity of the material here is greater than in the rest of the cupola and the connection of the trough with this region is not accidental.

Adjacent to the foothill of the Telluria region we find a section of so-called brittle ancient relief, which hardly rises above the surrounding plain; this region of crevasses of the same diagonal directions but special, at times hardly distinct. The relationships of these formations with the Telluria cupola are not fully clarified. In places the flow shaped masses, discharge from the cupola, cover clearly the brittle relief (but it seems that in places they also cover the ridge relief of the cupola itself) and sometimes brittle dislocations are converted into structures of the cupola gradually, increasing in dimension in the process and acquiring blurred outlines, as though they were "filling up". One gets the impression that they are a relatively ancient substrait, by whose remobilization the Telluria structures were formed.



Fig. 1. Structure of the west section of the Telluria region  
 1- plain lava, 2- main and secondary lineaments, 3- individual flows and regions of softened chaotic relief, 4- trough-shaped depressions, 5- volcanos, 6- lineaments on the plain

Southern Parquet of the Ishtar Terra (45-58° latitude north, 30-60° longitude east)

Whereas in the Telluria region we see signs of movement of matter along directions extending from the center of the cupola, the structure of the Parquet in the southwest of the Ishtar Terra testifies to the more or less unidirectional movement of the material (fig.2, photos 14 in (1)). The Parquet of this region occupies an area of nearly 1500 km in diameter and is located on the regional slope: in the northwest section it occupies altitudes of 3-4 km, in the southeast region it descends to 0-1 km, that is with a slope of nearly 2:1000.

This entire territory is divided by northwest furrows extending over hundreds of kilometers and 15-25 km wide into a series of lobes or flows; in the northwest they are 250-300 km wide, and in the southeast they are divided into lobes 40-100 km wide. Each such strip is divided by northwest and northeast furrows into a large number of orthogonal blocks. In the southwest these blocks are relatively large in dimension and somewhat indistinct outlines, and in the southeast frequent sharp northwest furrows begin to predominate, transversally to the direction of the flows, and gradually they are transformed into a system of crevasses resembling those of mountain and discharge glaciers. As a rule, these crevasses do not pass from one lobe to the other. The entire picture testifies to the movement of the superficial material in the form of differentiated flows. /63

The direction of movement is established according to the following characteristics. 1. The entire region as a whole is inclined to the southeast. 2. Inside the flows we find droplike depressions with diameter up to 50 km, from which "tails" extend southeast, valleys gradually contracting into narrow furrows. 3. The individual furrows form flexure type outlines, from which it is apparent that the central region of the system of flows is shifted to the southeast with regard to the edge regions. 4. In the northwestern region the parquet is covered on the edge with lavas, which occur also inside it in the form of numerous "lakes" and the furrows here are wide and smooth: the situation recalls that of the region of extension. In the southeast the picture corresponds rather to regions of compression, twisting and moreover it is apparent here, that in places the individual lobes cover the belt of linear dislocation. /64

ORIGINAL PAGE IS  
OF POOR QUALITY

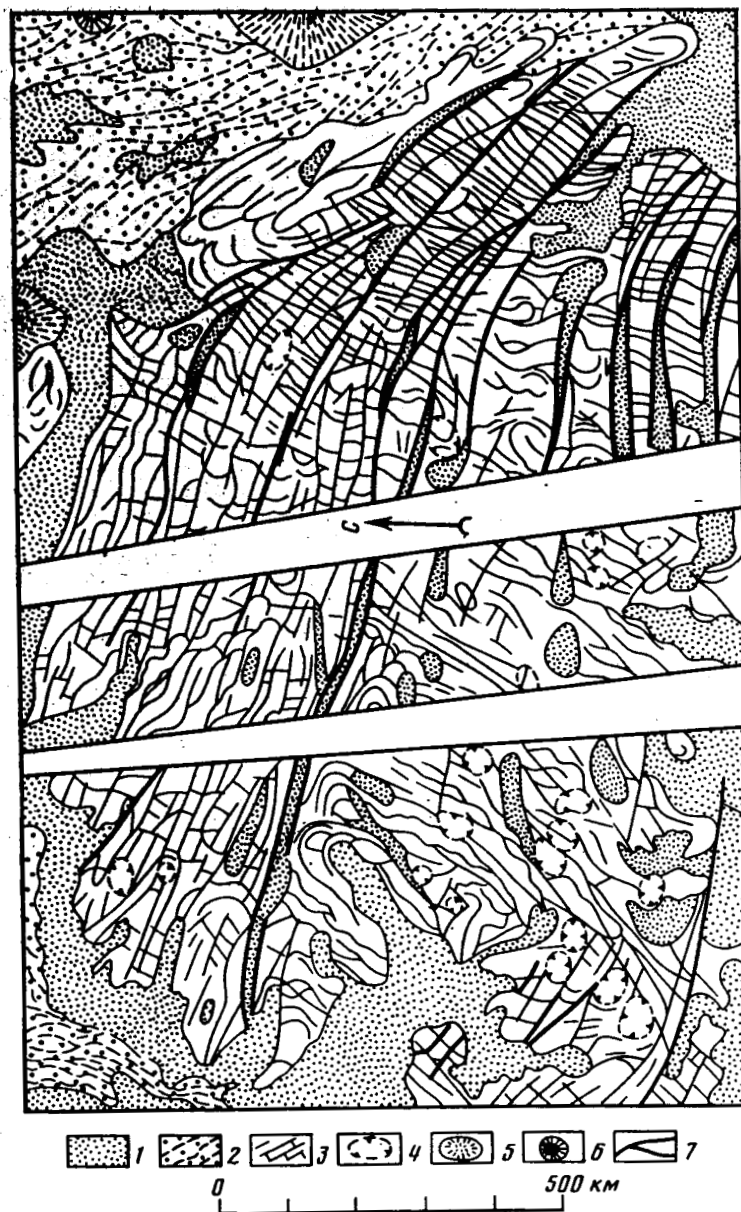


Fig. 2. Region of the southern parquet of Ishtar Terra

1- plain lavas, 2- belt of linear dislocations, 3- furrows and crevasses on the parquet, 4- isolated oval blocks, 5- volcanoes, 6- impact crater, 7- valleys dividing the lobes of the parquet

Everything seems to indicate that the superficial material moved over the entire area southeast in the form of flows with different speeds (the thickness of these flows in the frontal sections is nearly 1 km).



The southwest quarter of this region has the form of a flat smooth basin, bordered on the west, east and south by small swells, so that the material cannot move anywhere. Here the outline furrows become irregular although we find two prevailing directions, the furrows here become wide and are broken up, meandering, they are looped and their outline resembles the "standing" parquet of which we spoke at the beginning.

#### Region of Tefia

This elevated region is formed almost entirely of glacier type lobes, similar to the flows in the eastern region of the southern parquet, 50-100 km wide and with a course of 200-400 km, which are directed in the east-southeastern direction (fig. 3, photo 15 in (1)). They rise over the surrounding region by 800- 1500 m, on the average by 1000 m and are bordered by fairly deep projections (a few degrees). In the plane they are organized into a link system: the eastern blocks are shifted further southeast as compared with the western ones. Their surface is broken up by frequent transversal and rare longitudinal furrows and crevasses, forming an independent network in each block. (The crevasses rarely pass from one block to the other; the same phenomenon is observed also in the confluent lobes of the glaciers).

Sometimes in the stereograms with regards to relief it is apparent that the transversal crevasses have a fall towards the northwest, and probably they mark certain upthrusts with thrusts of the material to the southeast. In places they swell and grooves inside the lobes are bent like glacier drives, testifying to the shift of the material to the southeast.

In the rear portion these lobes are broken up by a sublatitude graben-shaped depression nearly 1300 km long, filled with lavas, and on its other edge we see the "sources" of the lobes, descending from the slopes of the elevation in the northwest portion of the territory under a slope of approximately 1:1000. This very elevation is a deformed ovoid, whose eastern portion is "swept" down along the slope in the form of many fine subconcentric wrinkles or folds; one of the glacierlike lobes, descending from the elevation, intersects the folds and is covered in its turn by young material, similar to the enormous rarified landslide.

We find another ovoid to the west: it is strongly twisted and depressed in the direction from west to east.

In the rear portions these structures obviously extended, were broken up and submerged, covered by lavas, and on the lava surfaces only the remnant of the flow structures remain. The frontal sections of the flows are either stopped in front of the local elevations, or move towards the adjacent region (although in general the region of contact is hidden under younger lavas, and the upthrust is only visible in two cases). There are no characteristics at all of movement or "extension" of the material under the region before the front of the flows.

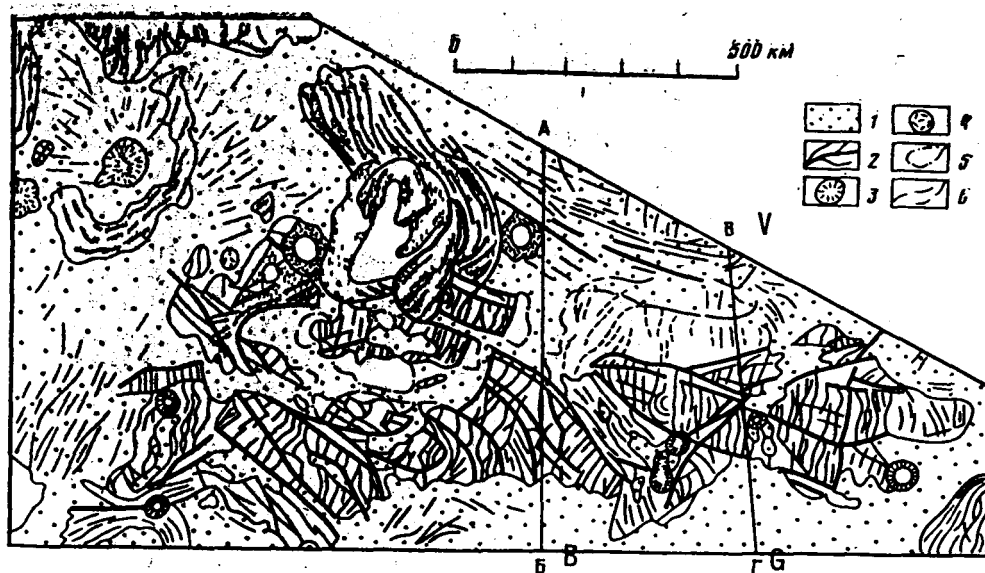


Fig. 3 Structure of the Tefia Region

1- plain lavas, 2- main and secondary lineaments of the parquet, 3- volcanoes, 4- craters, 5- outlines of the flows covered by lavas, 6- structures of flows, emerging from under the lavas. A-B, V-G are lines of profiles on fig. 4.

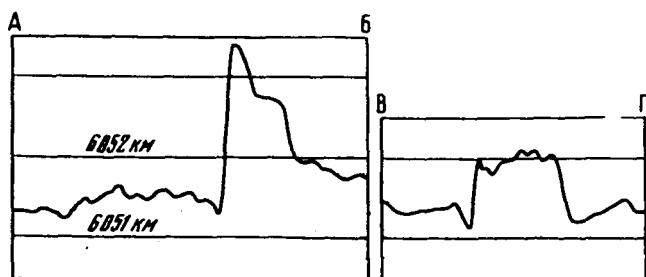


Fig. 4. Gypsometric profile related to fig. 3.

Рис. 4

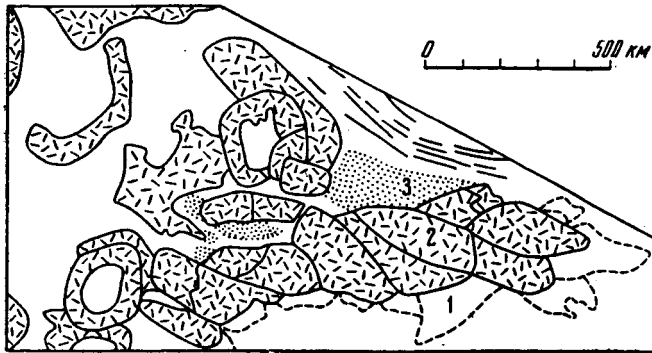


Fig. 5. Schematic reconstruction of the primary position of the flows of Tefia

- 1- contemporary position of the flows
- 2- primary position of the moving material
- 3- primary position of the materials covered now by lavas

On the profile it is apparent that with the approach to the edges of the flows the surrounding regions of up to 20 km begins to sink, submerged by 200 m from the edge of the flow (or more if we take into consideration the averaging of over a 50 kilometer measurement range), as though the region had sunk under the weight of these moving masses. /65

An attempt was made to reconstruct the primary position of these lobes of blocks (together with their portions which are now hardly visible under the lavas), shifting then in the northwest direction in such a way as to cover the rear trough, filled with basalts (fig.5) and to connect the separated flows of the same type. This scheme is totally conventional, but it makes it possible in the first approximation to evaluate the extent of the displacement. With such a reconstruction the entire material is collected into a single paleoelevation in the northwest, which was apparently divided by grabens and its portion moved in the southeastern direction over a distance of 40-60 up to 180 km. /66

### "Horseshoe" Parquet

At 62° latitude north, 119° longitude east, we find a volcano 1.2 km high with diameter 100-150 km and with several peak craters and lava flows, extending from the foothills over 100-200 km. From the volcano towards the east a very flat slope extends with total decrease of height of 500-600 m to 1000 km, and on this slope a horseshoe-shaped elevation is found with diameter 500 km, with its convex section turned inward on this slope. Its edge portion about 1 km wide is raised by 400-700 m over the surrounding region, and the central one by 200-300 m. From the north it is separated from the volcano by a depression nearly 100 km wide filled with lava.

The structure of the material of the elevation testifies to its movement

in the southern direction, downward along the regional slopes; in the central portions we see many conjugate fissures of 2 or 3 systems, similar to the fissures in the axial regions of the glaciers, and in the edge, horseshoe-shaped region we find meandering subconcentric wide furrows, which give the impression of a zone of injection, swelling and cracking of the material.

This shape can hardly be formed by the lavas, ignimbrites or any forms of turbidimetric flows simply because of the scales of the structure, not to speak of the peculiarity of the outline. This structure resembles rather the so-called aureoles of the foothills of the Olympus Volcano on Mars; the lobes of material with subconcentric outline, of diameter of several hundreds of kilometers, are clearly created by some extrusion, landslides and cracking of the material of the Olympus pedestal (15). And there as well as here the lavas are accumulated mainly on the lower side of the slope from the volcano and then moved with the entire mass downward on this slope. But whereas on Olympus this was obviously related to the partial melting of permafrost layers, on the "horseshoe" landslide it is possible to assume only a partial melting of the base of the crust's plate in the neighborhood of the volcano.

#### Northern Parquet of Ishtar Terra

This region extending over 3000 km in latitude and 800-1800 km in longitude, is divided into several structural zones, although combined under the general name of northern parquet (fig. 6, 7, photo 12, 13 in (1)).

The westernmost zone (see fig. 7, zone B) is located on the eastern slope of the Montes Maxwell at altitudes of 6-8 km and to the north of them, where it drops to 3 km. Within its limit we find remnants of the submeridional ridges, similar to the fold-upthrust structures of the steep western slope of the Montes Maxwell (see fig. 7, zone A). On these ridges is superimposed a system of northwest and northeast faults and small (a few tens of kilometers) of semi-arched structures, with the convex side turned downwards on the slope. With the decrease of the altitude in the movement from west to east (width of the zone 1-2 km to 200-300 km) the number of diagonal faults increases, and the remnants of the meridional ridges become gradually unrecognizable and disappear, and this zone

has a gradual transition to zone V (see fig. 7).

The boundary between the zones B and V correspond approximately to the bending of the slope or a wide trough, east of which the Montes Maxwell become a nearly horizontal plateau 350 x 500 km at an altitude of 6 km, surrounded by wide shallow slopes, descending to 3-4 km. This plateau is covered mainly by frequent northwest and northeast conjugated faults, dividing the region into rhombus-shaped sections of 20-40 km, extended in latitude, and in their turn they are divided into smaller blocks; sometimes faults of one direction predominate (see fig. 7, subzones  $V_2$ ,  $V_5$ ). To the south the plateau drops to the level of the plains, and on this slope the straight conjugate plains begin to bend, their southern sections assume rounded outlines, until finally they are replaced by wide (50-150 km) arched u-shaped structures, convex toward the south (see fig. 7, subzones  $V_3$ ); the outline of this region recalls the superimposition of tiles.

/67

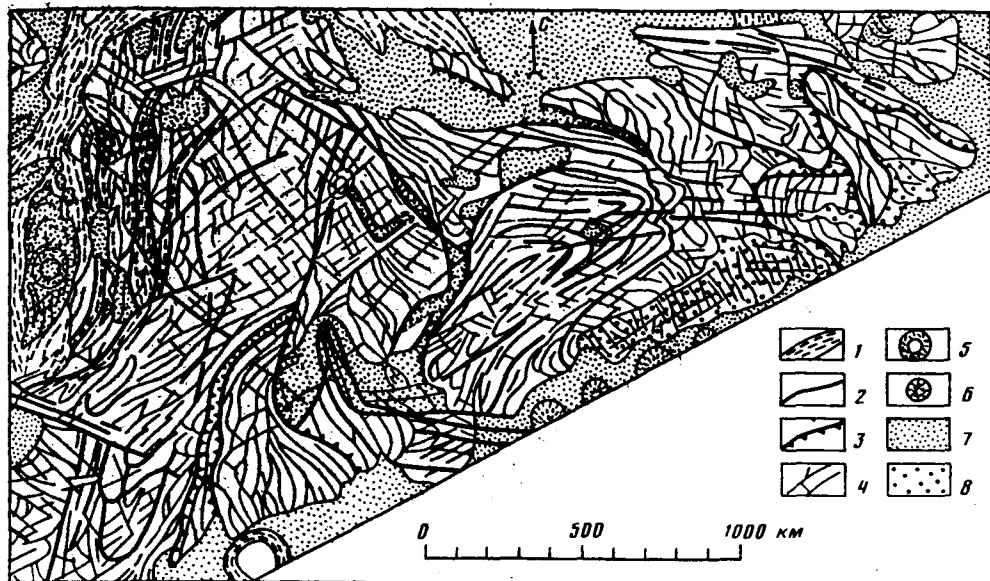


Fig. 6. Structure of the region of the northern parquet of Ishtar Terra  
1- belt of linear dislocations, 2- main faults, 3- projections, 4- ridges and furrows, 5- Cleopatra Crater, 6- volcano, 7- plain lavas, 8- lavas, carried along in the movement of the parquet

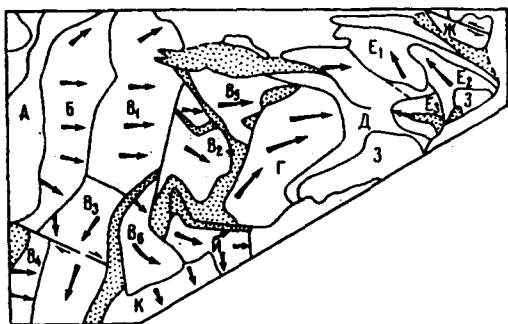


Fig. 7. Division of the northern parquet into regions. The points indicate the main zones of extension, the arrows the directions of movement of the material. The explanation of the letters is given in the text.

The block  $V_4$  (see fig. 7) is separated from the mountain mass by a large left handed shift, and here u-shaped structures, directed towards the east, in the direction of movement of the block are also superimposed on the conjugate diagonal fault.

The block  $V_5$  (see fig. 7) seems to be a triangular fragment, separated by large grabens from the neighboring regions, and is a limiting

/68

region of the parquet, where frequent west-northwest faults are subparallel to its northern boundary.

The zone  $V_6$  (see fig. 7) is formed by a fan-shaped lobe of material, dropping towards the south of the plateau. Narrow slightly meandering ridges, forming the "sticks" of this fan, are similar to folds or slivers, shifted in the eastern direction, and the extreme eastern ridges, clearly a section of lava plain with its rift system.

Further to the east the parquet is broken up within submeridional systems of faults and rift-shape depressions up to 100 km wide and nearly 1 km deep, filled with lava. The structure is similar to a giant rupture zone or a branch rift, along which the zones V and G diverged (see fig. 7) but of course the figure 100 km cannot be considered as a real displacement; the bottom of the graben may supply even for a comparatively slight horizontal shift.

From this point begins the most impressive section of this region (zone G, see fig. 7); a series of v- and u-shaped structures fitting into each other and consisting of conjugate ridges and furrows over hundreds of kilometers in them, forming as a whole a type of crust of a giant flow of plastic material, moving to the east. The axial portion of these zones is relatively uniform, and the relief here is relatively smooth as compared with the edge regions, and the edge

regions are formed of two subparallel belts converging to the east. It is impossible to determine the dimensions of the movement because of the absence of landmarks, but it is apparent that in the axial portion of the zone the shift to the east was much greater than on the edges.

In the eastern end of the zone the diagonal faults are connected into an arc, first sharp then to the east increasingly wider and open, until there remains only irregular submeridional structures, similar to the zone of twisting in which the flow of material is supported from the west (zone D, see fig. 7). The zone D is like a landmark squeezed between the zone G and the block of the zone E.

It is interesting to note that the maximum elevations are located here on the eastern edge of the parquet, and the material of zone G moved only to the southwest in the "sources", in the direction of the regional slope, and in general the axial portion of the flow is directed transversally to the slope.

At the eastern end of the Ishtar Terra in zone E, the outline of the structures changes once again: the region is divided into several large blade-shaped lobes. The unusual element is that some of them are directed toward the northwest, and others right next to them to the southeast, so that the impression is created of a simultaneous movement of the material in opposite directions. The detailed study of this region according to the stereograms makes it possible to consider that in all cases the material moved northwest, leaving from the southern end of Ishtar Terra, which is approximately 2 km higher than the northern side. But judging by the structural outlines, the displacement of material of the subzone  $E_1$  (see fig. 7) is similar to the sliding of a giant plane with the rupture region in its rear portion (like the west of Telluria) and in the sections  $E_2$  and  $E_3$  (see fig. 7) the material apparently flowed along the slope in a fairly plastic state (instead of the rupture zone in the "sources" of these lobes depressions are visible similar to the lava lakes in the plastic region of Telluria).

The zone Dc (see fig. 7) is a raised platform with central portion sunk and filled with lava: possibly this is an ancient ovoid, converted into a

parquet. It is interesting to note that the lavas are also subject to some deformations. In the southern swell of this structure it is apparent from the stereogram that the small crater is shifted by 12 km in a left handed displacement.

The zone Z (see fig. 7) has a smooth surface, covered with thin submeridional wrinkles and crevasses. Its northern limit is clearly recognized: it cuts off rough diagonal ridges and furrows of the parquet, which are sometimes detected inside this zone according to the slight bends of its surface but they differ greatly from the crevasses and the wrinkles of the zone itself. In the south this region blends readily with the flat ridge plain, framing the parquet and is obviously filled with lava; along the border with the parquet we see a change of presumably volcanic craters. It seems that the southern end of the parquet is covered by some massive coats of uncompleted movements on the parquet and the coats were carried along in the last stages of these movements, which led to their "crumpling". /69

Finally we should say a few words about zone I (see fig. 7) which is located at the intersection of the meridional rifts 1000 km long with the thick sublatitude fault 1500 km long, passing along the southern boundary of the parquet. This zone is a latitude swell 2-2.5 km high, in which the northern and southern borders repeat the consideration of the neighboring borders of the parquet. The swell is separated from the parquet by a lava depression with clear zone of extension and meandering of the type of a small rift, and the southern border is the edge of a narrow angular sunken plate with a network of dikes (zone K, see fig. 7). It gives the impression that this microplate K moved in the southeastern direction, and in the gap formed a rift zone arose, and in the region of maximum movement a hump of hot plastic material hove downward, partly covering or destroying material of zone G. At the same time subsequently this hump was destroyed into a number of slivers, thrusts towards the east, and then covered with the "fan" of zone B<sub>6</sub>, which by the way indicates the younger age of the western portion of the parquet (zone Z) as compared with the central region (zone G).

Thus on the Ishtar Terra east of the Montes Maxwell range we see signs of movement of large masses of material predominately in the eastern direction,



but also towards the south, northwest and northeast, as a function of the regional slope (the central portion of the region is an exception). The movement was accomplished with large plates (dimensions up to many hundreds of kilometers) with formation in their rear sections of regions of rupture and extension, and inside these plates, with the formation of conjugate faults, upthrusts and structures of flow.

Thus the structures of the parquet of different regions may be set up consecutively, and at one end we will have sections with chaotic outline and remnants of ancient structures ("standing" parquet), and at the other a "mobilized" parquet, with displacement of the material either in the form of glacier type of flows, or according to the type of giant landslides and gravitational overthrusts.

It should be noted that the lineaments of the parquet of different regions, although they are directed predominately in the northwest and southeastern directions, still form a uniform network: even in one region these orientations fluctuate within the limits of  $\pm 30^\circ$ , and the differences between the different blocks are even greater.

#### Prevalence of the Parquet Structures

Besides the described regions a strip of parquet edged the Lakshmi Plateau with its mountain ranges, a large area with flow structures ( $0.5 \times 10^6 \text{ km}^2$ ) is placed between the regions of Metide and Ullfrun ( $60^\circ$  latitude north,  $240^\circ$  longitude east) and also in a dozen and a half places among the lava plains find remnants of structures related to the parquet may be seen.

In certain sections (for example  $50-60^\circ$  latitude north,  $70-80^\circ$  longitude east) it is apparent that with the approach to the remnants of the parquet the lavas covering it are divided into a network of irregular polygons, comparable in dimension with the finest blocks of parquet (10-40 km). Probably the places of development of such polygonal lavas indicate the sections of buried parquet. It is also natural to assume that the neighboring remnants of parquet, are separated from the lavas, are connected under them into unified fields. If this interpretation is correct, the area of the blocks of Telluria and the southern

parquet increases to double, the total area covered by the parquet reaches at least  $16 \times 10^6 \text{ km}^2$  and we may speak of some overall process of "parquetization". (Of course this does not mean that the parquet occurs anywhere under lava plains; for example to the east the plains of Atalanta of the belt of linear dislocation occur so frequently that there is simply no room for the parquet).

/70

### Relationships with the Lavas and Belts of Linear Dislocations

The lavas cover almost everywhere the edge of the parquet and penetrate into its internal sections in the form of "gulfs" and "lakes". But there are cases of inverse relationships: the northern border of the northern parquet, flooded by lavas on the west, cut off in the east the belt of linear dislocations, which was formed obviously on ancient lavas. The subzone  $B_6$  (see fig. 7) of the northern parquet covers clearly plain lavas, and in their turn they cover the subzone G. The lavas in the zones Z and Zh cover the main structures of the parquet, but are themselves deformed in the same directions as the parquets. The lava troughs of Telluria and the rifts of Tefia and the northern parquet filled with lavas were undoubtedly formed in the last stages of parquetization.

Thus some lavas flowed before the beginning of parquetization, others simultaneously and in connection with the formation of the parquet, and still others after this process was completed. For the moment no examples have been detected for the parquetization of the youngest lavas, but it is quite possible that the formation of the parquet continues right until now.

On the other hand the calculations of the impact craters and the presumable impact circular structures show that per unit of area of the plain they are more numerous than per unit of area of the parquet, that is as a whole the parquet should be younger. This may be explained for example by the fact that the entire group of annular structures reflect the age of a lower and middle lava layers or even their support: Only the latest craters with clear discharges characterized the age of the latest eruptions, and the remaining are to some extent covered and "are transparent" from under the young lava strata on stable plains territories. On the parquet the ancient craters are found only in the calmest sections (for example in the "standing" parquet the craters are destroyed by

dislocation.

The interrelationship with the belt of linear dislocations are slightly better. If the typical linear belt is found with a region of the parquet, then it is either parquetized (region of "standing" parquet), or it is cut off and covered (northern edge of the northern parquet). The flows of the southern parquet are deflected to the south in the encounter with the belt, but cover it in places, and the same coat may be seen on the edge of Telluria. In places the parquet "eats up" even sections of the relatively young mountain frame of the Lakshmi Plateau.

But on the other hand such belts are conformed to the limits of Telluria and southern parquet, and the belt along  $60^{\circ}$  longitude east, at  $40-60^{\circ}$  latitude north is squeezed between these blocks, and in certain places it is difficult to determine where the belt begins and the parquet ends. Sometimes between them we see a gradual transition, where the belt expands, its linear ridges spread out, disintegrate into fine sections with transversal structures; and the belt is converted into parquet (area between the regions of Metide and Ulfrun).

The belts are generally of different age, but those of them which are related with the parquet obviously occurred before the beginning of parquetization or were formed simultaneously with the parquet on its limits with the stable blocks of the plain, and in the last stages of the process the mobilized parquet was partly dislocated and covered these belts or transformed them completely.

All ovoids falling within the sphere of action of the parquet were intensely transformed, and even in those which are arranged separately, usually phases of a process similar to parquetization are visible.

#### Mechanism of Formations

/71

Thus the following features are characteristic for the parquet.

1. The area distribution of the frequent fine (5-10 km width) smooth linear structures in several directions, among which we find very obviously both faults

unfold. This means that the stresses were not applied to the edges of any place of the crust, but were distributed over the entire area (12). The dimensions of the swells and the furrows and the distances between them indicate a low thickness of the deformed place (11,12,20) of not more than 5 km, and possibly even less than 1 km.

2. The systems of conjugate and v-shaped faults, caused by unilateral (predominately latitude) horizontal stresses. These systems are transformed in some places into u-shaped, lobe-shaped and flow-shaped structures with characteristics of differential horizontal displacement, sometimes thrust up by the frontal sections to the adjacent region.

3. Regions of extension, rupture crevasses, grabens and riftlike systems in the internal sections of the parquet, marking the rear zones of rupture of large plates and blocks, shifting in the general direction of the regional slope.

4. Parquet dislocations appear usually in the sections raised with regard to the surrounding plains by 1-3 km. The regional slopes in these regions constitute  $0.03-0.3^{\circ}$ , on the average  $0.05-0.1^{\circ}$ . If they are remnants, filled with lava and not manifested in the contemporary relief, they usually mark structural elevations of the prelava surface. With increase of the slope the cross system of faults are usually replaced by arc-shaped and flow-shaped structures.

All these characteristics could have arisen as a result of the effect of one out of two mechanisms: subcrustal asthenospheric flows, carrying away blocks of crust, or gravitational sliding and crushing of these blocks.

Both mechanisms are secured by the RT-conditions in the depth of Venus. At a temperature on the surface of  $480^{\circ}$  and an atmospheric pressure corresponding to the pressure of a rock column of just 300 m, the melting point of basalts will be reached nearer to the surface than on the Earth. For an average gradient  $20^{\circ}$  C/km, melting begins at a depth of 35-40 km, at  $30^{\circ}$  C/km, at 20-25 km, and in case of "geosynclinal" temperatures of regional metamorphism (2), only at 10 km, and below this limit one may expect the occurrence of asthenospheric convection. The strength of the crust, especially at the lower portion, should

decrease considerably because of the increased heating, and the blocks of this crust, having mainly a lubricating zone of partial melting, probably can slide and be deformed according to the type of gravitational thrusts.

The predominate confinement of the parquet to regions of shallow elevation seems to favor the hypothesis of asthenospheric flows. The purely isostatic maintenance of such elevations in Venus conditions seems to be hardly probable because of the too deep level of compensations required according to the geophysical data (18): it is assumed that they like the other large volcanoes Beta, Bell and Ulfrun, are maintained by dynamically ascending mantle jets ("plummage") but if in these volcanoes the heat exchange is accomplished also conductively and by means of lava meandering, then on the elevations with parquet, it will be mainly because of increase of thermal flow through the crust which has become thinner in large areas. Such structures as lava troughs and the melted zone of southwest Telluria, make it possible to assume that in places the ascending jets heated the crust to such an extent that they melted it almost to the surface.

It is difficult also to explain by local sliding the occurrence of such regional structures as the rift zones 900 km long, intersecting the northern parquet, and the troughs in the rear region of Tefia, 1300 km long.

Finally in the region of the north and southern parquet, Tefia and the area between the regions of Metide and Ulfrun, the masses moved predominately to the east and did not scatter in all directions from the maximum elevation. The flow in the central portion of the northern parquet moves to the east transversally to the regional slope. This is consistent with the predominantly submeridional and northeastern orientations of the belt of linear dislocations of the region of Atalanta and the more eastern ones which arose possibly as a reaction to the pressure in the eastern direction of the large Atalanta plate. The hypothesis may be put forward that these eastern orientations were created by tides slowing down. The appearance of Venus has retained traces of its faster rotation in the past (7), and now its rotation was stabilized in the resonant state with regard to the sun and the Earth; inasmuch as the planet rotates in the western direction, the tidal forces should carry along the belt towards the east. Possibly it is because of this that the ascending branches of the asthenospheric flows

/72

were deflected and flowed predominantly towards the east.

But facts such as the replacement of the network of conjugate faults in shallow sections by structures of flow on the steeper slopes, the appearance here too of plates with rear rupture crevasses, the crater shaped limitations of certain small plates, and also the small widths (up to 100-200 km) of the neighboring flows moving in a differentiated manner seems to favor gravitational slippings; since the asthenospheric flow can hardly be divided into such narrow jets or create such an extended structure as the Tefia parquet in the undisturbed region. The noncoincidence of the direction of displacements with the contemporary slopes may be explained by later bends of the surface: thus the northern edge of the northern parquet after its formation was covered by the lava of the plains, that is submerged.

With the hypothesis of asthenospheric flows it is most difficult to explain the upthrusts of the frontal sections of the flows of the parquet to the adjacent area in the regions of the southern parquet and Tefia, where this upthrust reaches 40-180 km on a very small slope.

On the Earth gravitational covers are displaced along the slope of a few degrees, and only occasionally can their frontal sections overcome small inverse slopes under the thrust of the rear masses and the weight of the thicknesses overhead. Moreover there is usually a lubricating layer at the bottom with evaporites, clays, with interstitial liquids (4,8,12) and others. On Venus there is no water and no traces of erosion are visible that is there are no significant sedimentary deposits with their potential lubricating strata, and the slopes constitute fractions of degrees. Therefore the slipping or flow of superficial material may be secured only by being heated to a sufficiently plastic state.

Naturally the question arises: how much must one heat these masses, and at what speed can they move and how long? But the rheology of rocks at subsolidus temperatures and low pressures has not been studied properly. With the approach to the melting point and especially the appearance of the first portions melt in the rock, viscosity begins to change very sharply. The

viscosity of ice also changes sharply when approaching the melting point. The viscosity also depends on small amounts of volatile impurities, for example carbonic acid, whose content in the crust is unknown. Moreover the rheology of small laboratory samples reflects only partly the rheology of large volumes of rocks, in which a considerable role is played by crushing and differential displacement of small blocks, which decreases sharply the strength of the entire volume of rock as a whole (12), just like a study of the classic properties of a homogenous ice sample in the laboratory does not make it possible to calculate the speed of catastrophic movement of a glacier.

Therefore an attempt was made to evaluate the lifetime of the flow according to the speed of its cooling in order just to get an idea of the magnitude. The following hypotheses were made. The flow in the upper layers of the Earth's asthenosphere in the opinion of many people begins when 1% drop of melt is produced in the rock. This takes place with a small addition of carbonic acid at  $1100^{\circ}\text{C}$  (7). Let us assume that Tefia flows with their average thickness 1 km contained 1% melt of basaltic composition in the entire volume (this is the average level and in the bottom of the melt probably it is greater, and it formed there the lubricating layer). To stop the movement, this melt must be crystallized and the temperature of the entire volume decreased let us say by  $100^{\circ}\text{C}$ .

/73

If for the flow of heated material a larger content of melt is needed, then its crystallization takes more time, that is we evaluate only the minimum time of cooling, and the same may also be stated if we have to cool it not by  $100^{\circ}$  but more to harden the flow. (In real conditions the cooling will take longer because of the conditional heat coming down into the bottom of the flow). Taking the heat of crystallization as 100 cal/g, the specific thermal capacity is 0.39 g/degree and the coefficient of thermal conductivity is  $5 \times 10^{-3}$  cal/cm x s x degree (10), and the temperature in the bottom of the flow 1100 and on the surface 460-480 $^{\circ}\text{C}$ , we find that this flow will cool down until it stops within a period of the order of 300 years. If its lobes during this period moved forward over a distance of 40-180 km, then the speed of displacement would be 130-600 m per year.

This is larger by 3-4 orders than the speed of displacement of the Earth's gravitational covers, but close to the speed of the Earth's glaciers: in Antarctica for example the coastal ice of low mobility move at a rate of 100 m/year and the lobes of the outlet glaciers 600 m/year (9).

Thus it is admissible that the Venus crust may in places heat up to such a state that large masses of matter begin to move, like glaciers, slipping and flowing on shallow slopes, overcoming small obstacles and forming structures similar to the glacier ones. Up to now such phenomena has not been observed on the planets of the solar system.

The mechanism of asthenospheric jets, creating arched elevations, horizontal stresses in the crust and its heating, and the mechanism of thermal gravitational flow of the crust from these elevations are not alternatives, inasmuch as in the conditions of Venus the second is a logical consequence of the first. They are also not the only tectonic mechanisms active on Venus, and their role in the general tectonic picture requires further study. Here it is only possible to put forward a few considerations in this connection.

#### Place of the Parquet in the Tectonic Picture

One of the main questions of the tectonics of Venus, discussed during the last few years is reduced to the following: plate tectonics active on Venus? On one hand certain data indicate the existence on Venus of this process, although on limited scales (16,17) but at the same time calculations showed that in the contemporary state of the Venus lithosphere it is impossible to have a subduction of the type on the Earth (13,18). The resolution of the available pictures did not make it possible to make a unique choice: if water is removed from the Earth's oceans and the relief of their bottoms is transformed in such a way as to compensate for this removal, and then the photography is carried out with the resolution of the pictures of "Pioneer Venus", then the central ocean ridges and systems of coastal arches will almost stop deferring from each other (18).

Now we may say definitely that on the photographed territory there are no signs of plate tectonics of the type on Earth: neither overall ridges with rifts,



nor structures of subduction zones. Instead of this on the Venus surface the following formations are widespread. 1. Giant sheet volcanoes, set in arched elevations, comparable in dimensions with the Icelandic or Hawaiian arch (here it is difficult to determine what part of the volume of these elevations is created by the accumulation of lava). 2. Annular volcano-tectonic erections (ovoids) of diameter about 100 km. 3. Regions of occurrence of the parquet. The individual areas of the parquet, including sections covered with lava, occupy an area of about 0.5-1.5 million  $\text{km}^2$ , and the raised blocks of Telluria, the northern and southern parquet, also including their presumed occurrence under lava, occupy approximately 4 million  $\text{km}^2$ .

/74

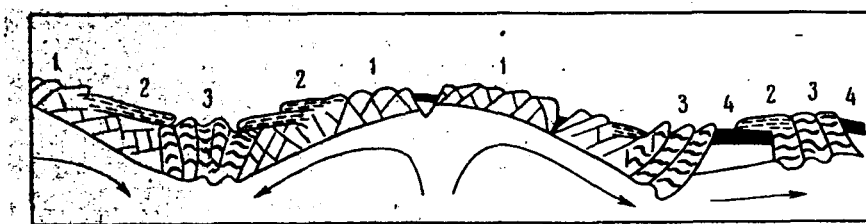


Fig. 1. Relationships of the Regions of the Parquet with their Frame

1- parquet with conjugate faults, 2- thermal and gravitational sliding, 3- belts of linear dislocations, 4- plain lavas on stable rocks; the arrows indicate the movement of the asthenospheric jets.

All these structures arose primarily above the ascending asthenospheric jets ("plumes"), heated, raising and occasionally tearing through the lithosphere, and the type of structure apparently depends on the dimensions and the conditions of the jets and the thickness of the lithosphere (fig. 8). Because of the enormous dimensions, it is difficult to call these regions hotpoints, but it is obvious that such jets must be one of the main mechanisms of heat exchange, considerably increased in the parquet regions, where the lithosphere was thicker, and the temperature radiant greater. It is possible that precisely because of the small thickness of the lithosphere these jets were not composed of single systems of rifts, digging up the lithosphere into sheets, and melted it each in its own section. By the way it is possible that the elements of such a combined rift system exists on the equatorial "continent" of Venus, the Aphrodite Terra (19).

/75

Figure 9 shows the simplified structural scheme of three basic regions of the parquet and their visibility. The occurrence of the parquet under lava was

detected mainly according to the characteristic large scale polygonal nature of the lava fields or according to their "ridged-wrinkled" surface. Therefore the picture is rather hypothetical in its detail: the regions of primary occurrence of the parquet occupy a smaller area and have more intricate features. But as a whole the general structure of the region may be seen on the scheme: three large parquet blocks, framed or divided into sections by linear belts of folds dislocations or relatively unstructured fine blocks. To these inter-parquet regions are added annular structures with diameters from dozens to hundreds of kilometers: probably some of them were formed with the oldest impact craters, whose remnants were retained in the structure of the sublava base, whereas these craters were destroyed on the mobile parquet. In any case the parquet blocks differ very much in structures from the interparquet regions and act with respect to them as totally independent units, certain microplates, although inside these blocks there is an actual structural transformation.

If we compare Venus with the Earth, then obviously it is closer not to modern Earth, but the Archean Earth. Because of the increased thermal flow (caused mainly by the high content of radioisotopes), the Earth's lithosphere in the Archean area was thicker, of the order 10-20 km, and apparently more plastic; it was divided into small "protocratons" (3,11,14). In this connection the thermal flow changed sharply over small distances (14) and probably there were long lived ascending mantle jets around which the nuclei of future plates grew, the Canadian, African and others (6), whereas in the calmer regions there might have been large circular negative structures (5); the greenstones belt were buried deeply, nor did they undergo any high topographical heaving (11). All this recalls Venus with its structural elevations over the postulated jets and passive intermediate lobes; the parquet takes here the place in a sense of the central ocean ridges.

In conclusion it should be noted that the concept of plate tectonics was developed on the material of the Earth and specifically for the Earth, to explain it modern tectonics, and the search for precisely the same mechanism on other planets would not necessarily be successful. Possibly the similarity of Venus tectonics is hidden in the early history of the Earth, but it is possible that the envelop of Venus developed somewhat differently from the very beginning,

and that with regard to Venus one should speak not of plate tectonics, but of plume tectonics.

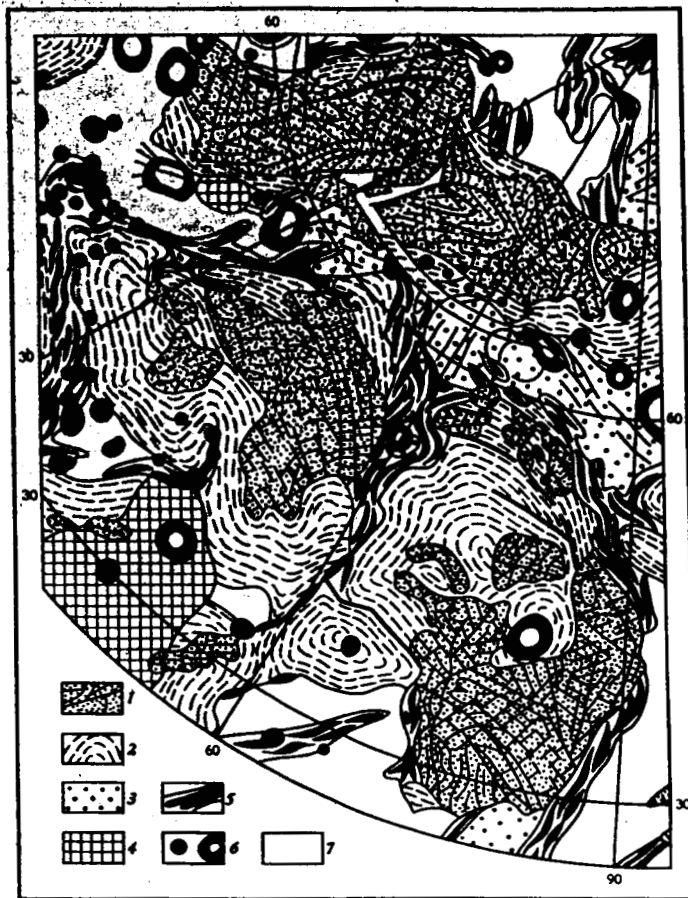


Fig. 9. Structural scheme of the blocks of northern and southern parquet of Ishtar Terra and Telluria

1- structures of the parquet on the surface, 2- presumed occurrence of the structures of the parquet covered with lava, 3- stable blocks, 4- volcano-tectonic elevations, 5- belts of linear dislocation, 6- annular structures "spiders" and ovoids, 7- lava fields with unclear structures

## LITERATURE

1. Barsukov, V.L., Sukhanov, A.L., Akim, A.L., et al, "Geological and Morphological Characteristics of the Northern Hemisphere of Venus", Geotektonika, No. 4, pp 4-25, 1986.
2. Belousov, V.V., Zemnaya Kora I Verkhnyaya Mantiya Materikov (Earth's Crust and upper Mantle of the Continents), Moscow, Nauka Press, 123 pp., 1966.
3. Berk, K., Duke, G.F., Kidd, U.S., "Prevalence of Horizontal Movements, Island and Microcontinental Collisions during the Late Permian Stage" in the book Rannyya Istoriya Zemli (Early History of the Earth), Moscow, Mir, pp 123-143, 1980.
4. Vile, G., "Structure and Tectonic History of the Washito Mountains, Arkansas" in the book Sila Tyazhesti I Tektonika (Force of Gravity and Tectonics), Moscow, Mir, pp.356-372, 1976.
5. Glukovskiy, M.C., Moralev, V.M., Kuc'min, M.N., "Tectonic and Petrogenesis of the Protoarchaic Complex of the Atlantic Plate in Connection with the Problem of Ophiolites" Geotektonika, no.6, pp. 103-117, 1977.
6. Goodwin, A.M., "Giant Meteoritic Bombardment and Development of Continental Crusts" in the book Rannyya Istoriya Zemli (Early History of the Earth), Moscow, Mir, pp. 87-107, 1980.
7. Zharkov, V.N., Vnutrenneye Stroyeniye Zemli I Planet (Internal Structure of the Earth and the Planets), Moscow, Nauka, 415 pp.
8. Lemoine, M., "On the Tectonics of Gravitational Slipping in the Western Alps" in the book Sila Tyazhesteie I Tektonika, Moscow, Mir, pp. 207-222, 1976.
9. Losev, K.S., Antarkkticheskiy Lednikovyy Pokrov (Antarctic Ice Cover), Moscow, Nauka, 159 pp.
10. Frenkel', M.Ya, Zabaluyeva, Ye.V., "Hardening of the Effusive Melt on Venus and on the Earth", Geokhimiya, no. 9, pp.1275-1279, 1983.
11. Shou, D.M., "Development of the Early Continental Earth's Crust, Part 2, Prearchaic, Protoarchaic and Later Eras" in the book Rannyya Istoriya Zemli (Early History of the Earth), Moscow, Mir, pp 40-62, 1980.
12. Yaroshevskiy, V., Tektonika Razryvov I Sklavok (Tectonics of Faults and Folds), Moscow, Nedra, 215 pp.
13. Anderson, D.L., "Plate Tectonics on Venus", Geophys. Res. Lett., no. 4, pp 309-311, 1981.
14. Engel, A.E.J., Itson, S.P., Engel, C.G., et al, "Crustal Evolution and Global Tectonics: Petrogenetic View", Geol. Soc. Amer. Bull., v. 85, No. 6, pp.843-858, 1974.

15. Harris, S.A., "The Aureole of Olympus Mons on Mars", J. Geophys. Res., v. 82, no. 20, pp. 3099-31-8, 1977.
16. Head, J.W., Solomon, S.C., "Tectonic Evolution of the Terrestrial Planets", Science, v. 213, pp. 62-76, 1981.
17. Jangle, P., Jannsen, D., "Tectonics of the Southern Escarpment of Ishtar Terra on Venus from Observations of Morphology and Gravity", Earth, Moon and Planets, v.31, pp. 141-155, 1984.
18. Phillips, R.J., Malin, M.C., "Tectonics of Venus, Annual Rev. Earth and Planet", Science, Palo Alto, California, v. 12, pp. 411-423, 1984.
19. Schaber, G.G., "Venus: Limited Extension and Volcanism Along Zones of Lithospheric Weakness", Geophys. Res. Lett., v. 9, pp. 499-502, 1982.
20. Solomon, S.C., Head, J.W., "Venus Banded Terrain: Tectonic Models for Band Formation and their Relationship to Lithospheric Thermal Structure", J. Geophys. Res., v. 89, no. B8, pp. 6885-6897, 1984.

Geological Institute of the  
USSR Academy of Sciences

Received by Editors  
November 10, 1985